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## **The Role of Technology in the Future of Smallholder Agriculture**

Literature Review



The benefits of smallholder-based food production systems in the developing world have been written about extensively in both a scientific and policy context. This paper explores the literature to understand the role of modern agricultural technologies towards improving smallholder production and livelihoods.

## Overall Observations about the Future of Smallholder Farming

Many observers have concluded that sustainable intensification of smallholder farming is the best hope for keeping up with food demand and alleviating poverty in the developing world (e.g. Hounkonnou *et al*, 2012). Jayne *et al*, 2010, studied survey data from five countries in eastern and southern Africa and concluded: "...there is no single or deterministic "future" of the small farm in Africa. The decisions made by governments primarily and international organizations secondarily will largely determine the future of smallholder agriculture in the region."

They determined that without renewed attention to sustained productivity and growth, most small farms in Africa will become increasingly difficult to maintain. Addressing this pending issue will require increased public investments in agriculture, a policy environment that supports private investment in input, output and financial marketing. The provision of key support services, a more level global trade policy environment, supportive donor programs, and improved governance are also necessary. Jayne *et al*, 2010 stated that most of these challenges can be met and meaningful progress will start when there is a critical mass of commitment among African leaders and governments in developed countries."

They further state that, "...strategies attempting to link African farmers to markets must take account of how low crop productivity and inequality in productive assets constrain most smallholders' ability to participate in markets." They observed what appears to be a vicious cycle in which low surplus production constrains the development of markets. That in turn constrains smallholders' ability to use productive farm technologies in a sustainable manner which reinforces semi-subsistence agriculture.

Asfaw *et al*, 2012, surveyed smallholder farmers in Tanzania and Ethiopia and also concluded that, "The potential direct role of agricultural technology adoption on improving rural household welfare, as higher gain of consumption expenditure from improved technology also means less poverty."

Falconnier *et al*, 2017, concluded that there was a need for a "strategic and multi-sectoral combination of interventions to improve livelihoods" for smallholders in Southern Mali. They envisioned a scenario in which "Additional programs to promote Integrated Pest Management, small-scale mechanization and mineral fertilizer on traditional cereals could allow a drastic increase in productivity and would lift 94% of the farm population out of poverty."

# Factors Influencing Technology Adoption

Overall, risk is a key limitation for the use of technologies by farmers. Wolgin (1975) used a data set from Kenya to document this and how it is confounded by limited access to credit. His conclusion was, “Risk plays an important role in farmer decision making; farmers are efficient in their allocation of resources; and lack of credit availability is a major bottleneck in obtaining increased agricultural productivity for the regions studied in Kenya.”

Kassie *et al*, 2013, studied the adoption of sustainable agricultural practices (SAPs) among smallholder farmers in Sub-Saharan Africa with a focus on Tanzania. They found that, “rainfall, insects and disease shocks, government effectiveness in provision of extension services, tenure status of plot, social capital, plot location and size, and household

assets, all influence farmer investment in SAPs. Policies that target SAPs and are aimed at organizing farmers into associations, improving land tenure security, and enhancing skills of civil servants can increase uptake of SAPs in smallholder systems.” In particular they found that land tenure is a key driver.

Chirwa, 2005, studied adoption technology adoption among maize farmers in Malawi and found that, “...fertilizer adoption was positively associated with higher levels of education, larger plot sizes and higher non-farm incomes, but negatively associated with households headed by women and distance from input markets. The adoption of hybrid seeds is positively associated with market-based land tenure systems and fertile soils, but negatively associated with age of the farmer and distance from input markets.”





A similar analysis for maize farmers in the central highlands of Ethiopia found that, “level of education, household labour, farm size, extension services, farm income, and timely availability of improved maize seeds significantly influence the adoption and intensity of use of improved maize.” (Alene *et al*, 2000).

Ike and Inoni, 2006, concluded that smallholder yam farmers in Nigeria are more likely to utilize technologies such as fertilizers, pesticides and improved plant genetics if they are better educated and therefore better equipped to acquire technological knowledge which allows them to produce higher yields.

Patt *et al*, 2010, found that many farmers did not understand insurance or the probability of loss. That knowledge gap is a barrier to getting loan guarantees that might allow them

to use technologies such as higher yielding plant varieties.

Apata *et al*, 2018, found that gender is a driver for poverty among smallholder farmers in Nigeria as female farmers were less likely to have title to the land they farm and less access to credit that enables them to invest in useful technologies.

Saka *et al*, 2005, found that relative cultivar yield potential and the frequency of extension contact were the two most important factors that determine choice of cultivation of improved rice varieties among the farmers in Southwestern Nigeria.

Access to micro credit was found to be a “powerful anti-poverty tool” for Nigeria as it has been in many other regions (Anyuiro and Oriaku, 2011).

## Irrigation-related Technologies

In Africa and other drought prone regions, farmers hesitate to invest in inputs because the potential for crop loss during intermittent drought and crop failure occurs on a one in five-year basis. Rockstrom *et al*, 2002, argue that, “...some of the most exciting opportunities for water productivity enhancements in rainfed agriculture are found in the realm of integrating components of

irrigation management within the context of rainfed farming, e.g. supplemental or micro irrigation for dry spell mitigation.”

Combining such practices with management strategies that enhance soil infiltration, improve water holding capacity, and plant water uptake potential, can positively impact agricultural water productivity.



## Improved Genetic Resources

Asfaw *et al*, 2012, surveyed farmers in Ethiopia and Tanzania to try to understand why there was limited adoption of improved varieties of chickpea and pigeon pea in spite of strong evidence of benefits from doing so. They found that key barriers were access to a local supply of seed and a lack of access to information. They concluded that a more financially and institutionally flexible seed system that meets the needs of a diverse group of farmers and reduces the current seed supply crises, is crucial to agricultural growth and commercialization. This requires lifting

entry barriers of the private seed industry and encouraging the growth of the informal sector by providing access to basic or foundation seed and extension advice on seed production, processing, treatment and storage.

A study by Yousouf *et al*, 2002, found that Bt cotton had higher yields and lower insecticide costs than conventional cotton so that although seed costs were twice as high, the gross margins for the Bt growers were higher for the farmers using the technology.





## Pest Management Issues

Pretty *et al*, 2015, reviewed efforts to develop IPM programs for smallholder farmers in Africa and Asia and found that crop pests, diseases and weeds pose a substantial challenge to global food security and can be mitigated through a substantial IPM strategy. They also observed that a package of technologies and practices is often necessary to control a pest, disease or weed. These must be developed in partnership with local farmers to cater to local circumstances while increasing farmers' knowledge through participatory research."

Pests can be severely limiting for smallholder cultivation of export crops. "The most severe problem faced by cacao farmers in the region is the occurrence of pests and diseases. At a global level, yield loss due to disease is estimated at about 30%. In west Africa it ranges from 10 to 80%." Cacao farmers in west and central Africa receive subsidies and state support to control pests and disease and until the early 1990s, the Cameroon government provided farmers with fungicides at no cost. Duguma *et al*, 2001.

Mwatawala *et al* tested three IPM systems for control of an invasive fruit fly damaging mangos in Tanzania. All three systems were effective, but the authors concluded that while a system employing a commercial product was best suited to commercial farmers targeting organic and export markets, commercial farmers targeting regional markets would best use a system including a broadcast spray. For smallholder settings, their recommendation was a system employing a locally formulated, botanical bait based on crude extracts of *Derris elliptica*, molasses and brewery yeast waste. This is a good example of how IPM technologies can be customized for the specific class of grower.

Smallholder potato growers in Uganda face significant disease and insect issues but have very limited knowledge of safe pesticide-handling practices, ability to understand product labels, or input from knowledgeable extension officers. Okonya and Kroschel, 2015, who studied this situation concluded that the best path forward for these farmers was an



integrated pest management system utilizing lower hazard options such as fungicides in WHO class U (unlikely to present acute hazard in normal use). In Bolivia, Jors *et al*, 2014, documented sustained improvements in safe pesticide handling and use from farmers who participated in a Farmers Field School program.

Smallholder sweet potato growers in the highlands of Papua New Guinea suffer significant losses from insects and diseases but lack the biological and technical knowledge to actively manage the pests. This “hampers efforts to establish food security and constrains the development of sweet potato as a cash crop” (Gurr *et al*, 2016).

Mengistie *et al*, 2017, studied smallholder pesticide use practices in the Rift Valley of Ethiopia. Although current use patterns are not safe for farmers, they argue that the solution is not the avoidance of all pesticides, but rather, “Bringing in new actors such as environmental authorities, suppliers, NGOs and private actors, as well as social and technological innovations, may contribute to changes in the actual performance of these pesticides buying and using practices.”

In a meta-analysis of intercropping with legumes in Africa (Himmelstein *et al*, 2017) the most clear-cut benefits in terms of yield and

gross income were seen where that practice was supplemented with the use of herbicides to achieve adequate control of unwanted vegetation.

One vision for the future of pest management in regions like East Africa is local production of plant-based insecticides. Historically, pyrethrum was produced by smallholder farmers in Kenya (Stevenson *et al*, 2017). This would require outside technical support for efficacy and safety oversight. One specific potential crop for production of a botanical crop protection tool (*Ageratum conyzoides*) has been described by Rioba *et al*, 2017.

Improved pest management is recognized as a major potential for smallholder agriculture. In a study of low cost improvements in agronomic practices for cassava production in Africa, Ekelema *et al*, 2016, describe a cooperative project involving Nigerian agriculture and regulatory government agencies, farmer organizations, independent farmer groups, NGOs and chemical companies. The goal is to develop “safe, practical, affordable, profitable and sustainable techniques that will best address weed management in cassava.” The authors believe that when combined with correct use of herbicides, yields have the potential to approach double the current national average.

## Approaches for Conservation Agriculture

Tillage leads to soil degradation over time, but for smallholder farmers there is a shortage of viable mechanized options to allow direct drilling of seed. Johansen *et al*, 2011, found that “In Africa, the introduction of animal-drawn rippers and direct seeders, originally developed for small-scale farmers in Brazil, is considered as a major breakthrough to small-scale farmer mechanization.” They went on to describe planter attachments for two wheel tractors that have been successfully used to allow seeding and fertilizer placement in ways that reduce fuel and labor costs and make seed and fertilizer inputs more efficient.

However, the authors argue that even greater benefits could be achieved if there were more safe and effective herbicide options available for resource-poor farmers that could be integrated with small-scale planter technologies.

Shiferaw *et al*, 2009, observe that in addition to policies and institutional mechanisms that encourage conservation agriculture, “linking farmers to better markets for their produce and inputs like fertilizer and credit generally makes a positive contribution in raising the returns to land and labor in agriculture.”



# Fertilization

Advocates of “low input” agriculture tend to reject inputs of fertilizers from outside of the region; however, research suggests that this issue may not be best treated as an “either/or” decision. For instance, Akinnifesi *et al*, 2007, documented synergistic effects on maize yields in Malawi when inorganic nitrogen and phosphorus fertilizers were combined with organic contributions from intercropping with the nitrogen fixing legume *Gliricidia sepium*.

Saka *et al*, 2005, found that while the greatest increase in yield potential for Nigerian rice farmers was due to improved cultivars, the yield of local varieties was also improved with fertilizer input.

Tanner *et al*, 1993, found that more fertilization increased wheat yield in Ethiopia, but that it also increased the density of wild oats and broadleaf weeds which increased labor requirements. It also increased the incidence of stripe rust. The increase in use of fertilizer needs to be combined with other technologies such as an effective herbicide option and rust resistance crop traits.

Snapp *et al*, 2002, studied the potential for smallholder farmers in Malawi to utilize legumes within their production system as a source of nitrogen for the main maize crop. While there was a nitrogen contribution from the legumes, the likelihood of adoption would depend on the market potential of the legume crop and the impact on marginal maize yield potential.





## Storage Technologies

Denning *et al*, 2009, point out that post-harvest pests like the larger grain borer can undo benefits of crop yield enhancement in countries like Malawi. “There are no reliable national estimates of the losses caused by this pest. Without chemical treatment, household losses of 40% to 100% have been reported.”

Tefera *et al*, describe a metal grain bin technology that has shown considerable benefit for farmers. They observed that, “Secure post-harvest storage empowers

smallholder farmers. Post-harvest storage facilities not only offer the opportunity to alleviate hunger between staple crops harvest, but farmers are also able to improve farm incomes by storing crops and selling them at premium prices when demand outstrips supply later in the postharvest period.”

Because quality is an important determination of crop retail prices, effective storage is crucial to improve agricultural incomes and food security for smallholder farmers.





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**CropLife Foundation**

156 15TH STREET N.W. SUITE 400  
WASHINGTON, DC 20005  
USA

TEL +(202) 269 1585

FAX +(202) 355 1419

CONTACT@CROPLIFEFOUNDATION.ORG

CROPLIFEFOUNDATION.ORG

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